CHAPTER 10

PRACTICE EXERCISES

SECTION I MULTIPLE CHOICE

Questions 1 and 2. Two charges are arranged on the corners of a square as pictured.

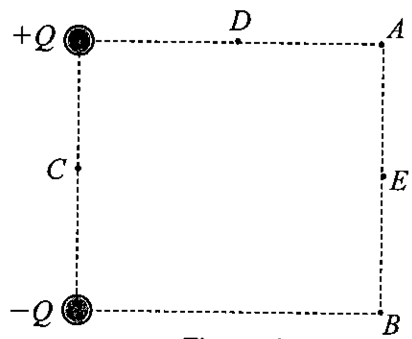

Figure 6

1. The direction of the net electric field at the center of the square is

   (A) ↑ (B) → (C) ↓ (D) ↙ (E) ↗

2. The magnitude of the field will be strongest at

   (A) A (B) B (C) C (D) D (E) E

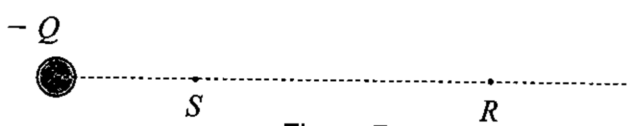

Figure 7

3. The figure shows an isolated negative charge fixed in position. Point R is 3 times as far away as point S. The ratio of the field strength at S to the field strength at R is

   (A) 9 to 1 (B) 3 to 1 (C) 1 to 9 (D) 1 to 3 (E) 1 to 1

4. A 2 μC charge with mass 0.1 kg accelerates at 2 m/s^2 in a uniform electric field. The magnitude of the field is most nearly

   (A) $10^5 \frac{\text{N}}{\text{C}}$ (B) $10^{-5} \frac{\text{N}}{\text{C}}$ (C) $2 \frac{\text{N}}{\text{C}}$ (D) $0.2 \frac{\text{N}}{\text{C}}$ (E) $0.1 \frac{\text{N}}{\text{C}}$

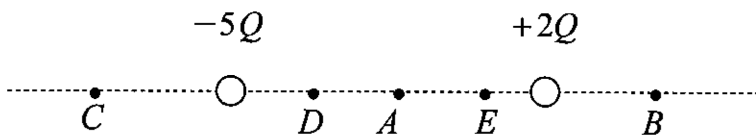

Figure 8

5. Charges $+2Q$ and $-5Q$ are situated as shown. At what point could the electric field be equal to 0?

(A) A (B) B (C) C (D) D (E) E

6. Starting from rest a charge moves a distance d along uniform field lines after which it has a speed v. If an identical charge moves from rest through a distance $2d$ along the same field lines it will have a speed of

(A) $\frac{1}{2}v$ (B) $\frac{1}{4}v$ (C) $\sqrt{2}v$ (D) $2v$ (E) $4v$

7. Charge q with mass m is a distance R from a second charge $2q$ with mass $2m$. If F and a are the force and acceleration of the first charge, the force and acceleration of the second charge are

(A) F and $2a$ (B) $2F$ and a (C) $2F$ and $\frac{1}{2}a$ (D) $2F$ and $2a$ (E) F and $\frac{1}{2}a$

Chapter 10 PRACTICE EXERCISES

Section II Free Response

1. Two charges are located along the x-axis, $-3\ \mu C$ at the origin and $+6\ \mu C$ at the point (2, 0).
   (a) Determine the electric field at the point $(-1, 0)$.
   (b) Find the magnitude and direction of the force on an electron placed at $(-1, 0)$.
   (c) Determine the point on the x-axis where the electric field is 0.

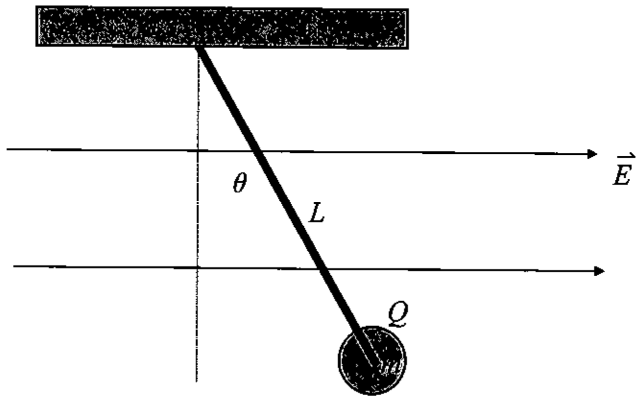

Figure 9

2. A nonconducting sphere of charge $+Q$ and mass m is attached to a string of length L and hangs from a ceiling. When a uniform electric field directed horizontally is introduced, equilibrium is eventually established with the mass hanging at an angle θ with respect to the vertical. In terms of g and the given quantities, find the strength of the electric field and the tension in the string.

3. A positive charge q is initially at the origin and moving with velocity $v_0 > 0$ opposite to a uniform electric field E directed in the negative x direction. The effects of gravity are negligible.
   (a) Determine the maximum coordinate x the charge attains.
   (b) Determine the time it takes for the charge to return to its starting point.
   (c) Determine the speed of the charge when it has the coordinate $-x$.

Answers and Explanations

MULTIPLE CHOICE

1. The answer is C. At the center, the field created by the top left charge is directed along the diagonal away from that charge, while the field created by the bottom left charge is directed toward it along the other diagonal. Since the two fields have the same strength, the horizontal components cancel out.

2. The answer is C. This point is closest to both charges, and the two separate fields created by each charge are in the same direction—down—so there is no cancellation.

3. The answer is A. The field at S is $3^2 = 9$ times bigger since R is 3 times further away.

4. The answer is A. $netF = ma$ implies $qE = ma$. Substituting, you get

$$E = \frac{(0.1)(2)}{2 \times 10^{-6}} = 10^5 \ \frac{\text{N}}{\text{C}}$$

5. The answer is B. At this point, the two separate fields oppose each other. Because B is closer to the smaller charge, the effect of the smaller charge can be large enough to offset the field due to the bigger charge. At C, the two fields oppose each other but can never cancel out due to the proximity to the larger charge. At A, D, and E, the fields reinforce each other.

6. The answer is C. Since $F = qE$ is constant, the second charge has twice as much work done on it by the field. Thus, it will have twice the KE as the first charge.

$$\tfrac{1}{2}mv'^2 = 2(\tfrac{1}{2}mv^2) \Rightarrow v' = \sqrt{2}v$$

7. The answer is E. Each charge exerts an equal but opposite force on the other. Since the force on the second is the same, it will have $\frac{1}{2}$ the acceleration since it has twice the inertia.

FREE RESPONSE

1. (a) The field due to the $-3\ \mu$C charge points in the $+x$ direction and has magnitude

$$E^{-3} = 9 \times 10^9 \ \frac{(3 \times 10^{-6})}{1^2} = 2.7 \times 10^4 \ \frac{\text{N}}{\text{C}}$$

The field due to the other charge points in the $-x$ direction with magnitude

$$E^{+6} = 9 \times 10^9 \ \frac{(6 \times 10^{-6})}{3^2} = 0.6 \times 10^4 \ \frac{\text{N}}{\text{C}}$$

The overall field points in the $+x$ direction with magnitude

$$E = (2.7 - 0.6) \times 10^4 = 2.1 \times 10^4 \ \frac{\text{N}}{\text{C}}$$

(b) An electron placed at this point will feel a force in the opposite direction to the field, the $-x$ direction. The magnitude will be

$$F = qE = (1.6 \times 10^{-19})(2.1 \times 10^4) = 3.4 \times 10^{-15} \text{ N}$$

(c) Between the two charges on the x-axis, the two fields will reinforce each other. To the left of the origin, closer to the smaller charge, the fields tend to cancel out, and if the point is chosen properly, the two contributions will cancel out. This will occur at some point $x < 0$.

$$k\frac{3\times10^{-6}}{x^2} = k\frac{6\times10^{-6}}{(2-x)^2}$$
$$\frac{(2-x)^2}{x^2} = 2 \Rightarrow \frac{2-x}{x} = \pm\sqrt{2} \quad \Rightarrow x = \frac{2}{1-\sqrt{2}} = -4.83 \text{ m}$$

Only the −root gives a negative x-value.

2. This is an equilibrium problem. You can find the net force components in each direction and set them equal 0 to get the two unknowns.
From the freebody diagram (figure 10), you have

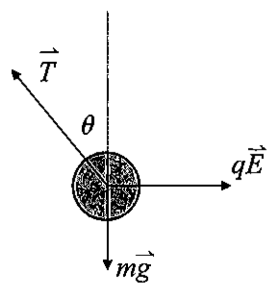

Figure 10

$netF_x = 0$	$netF_y = 0$
$T\sin\theta - qE = 0$	$T\cos\theta - mg = 0$
$T\sin\theta = qE$	$T\cos\theta = mg$

Dividing the two equations gives you

$$E = \frac{mg}{q}\tan\theta$$

The tension is given directly from the y-components:

$$T = \frac{mg}{\cos\theta}$$

3. (a) The acceleration of the charge follows from Newton's second law.

$$netF = ma = qE \Rightarrow a = \frac{qE}{m} \quad \text{(in } -x \text{ direction)}$$

The fourth motion equation can be used to determine the maximum x-coordinate.

$$v^2 = v_0^2 + 2a\Delta x$$

$$0 = v_0^2 - 2\frac{qE}{m}x \Rightarrow x = \frac{mv_0^2}{2qE}$$

(b) Since the static electric force is conservative, the charge will return to the origin with the same speed but in the opposite direction. The first motion equation will then give the time.

$$v = v_0 + at$$

$$-v_0 = v_0 - \frac{qE}{m}t \Rightarrow t = \frac{2mv_0}{qE}$$

(c) Use the fourth motion equation.

$$v^2 = v_0^2 + 2a\Delta x$$

$$v^2 = v_0^2 - 2\frac{qE}{m}(-x) = v_0^2 - 2\frac{qE}{m}\left(-\frac{mv_0^2}{2qE}\right)$$

$$v = \sqrt{2}v_0$$